PROJECT ARTEMIS

VISUAL NAVIGATION FOR FLYING ROBOTS

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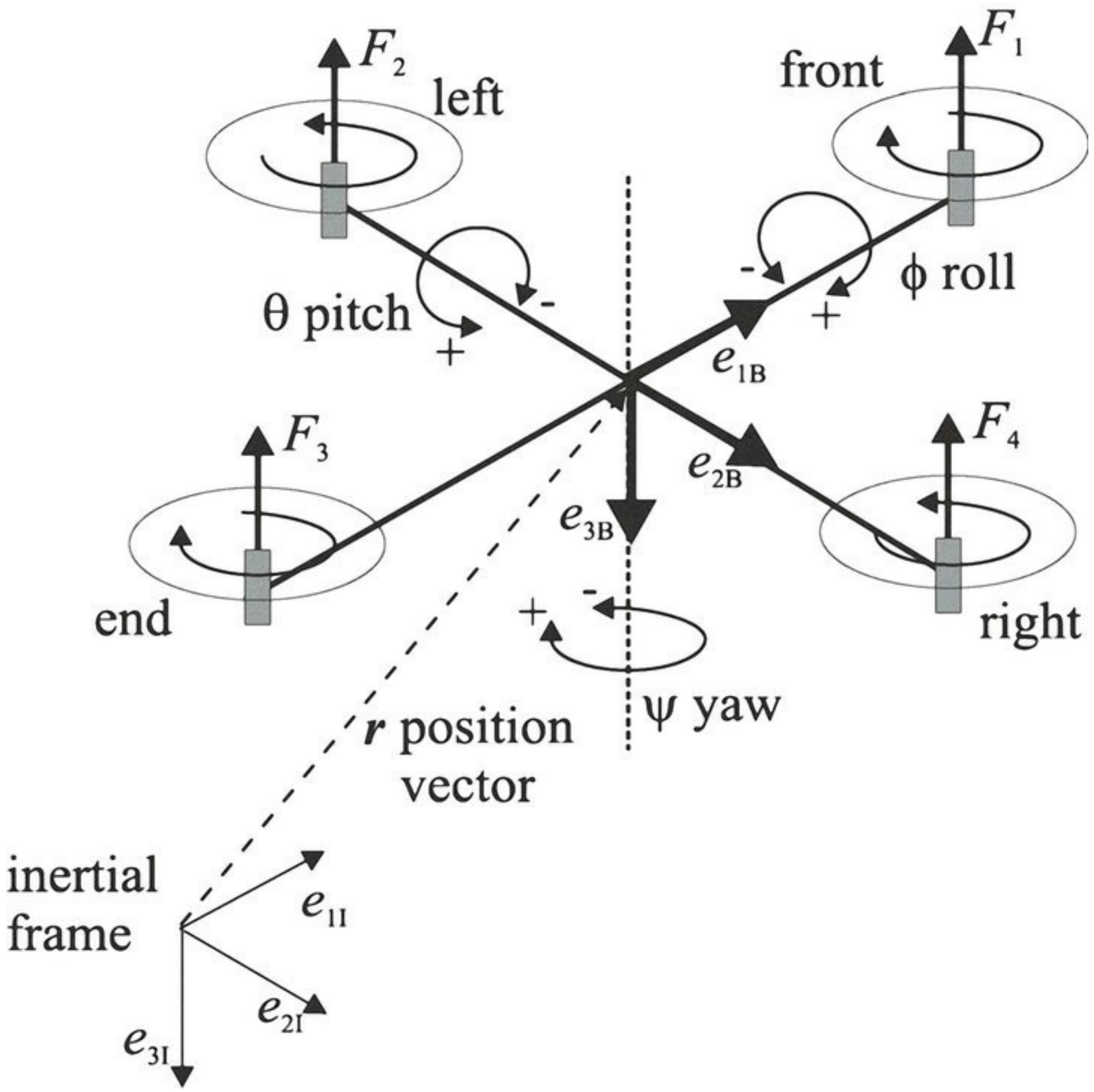
STATE OF THE INDUSTRY

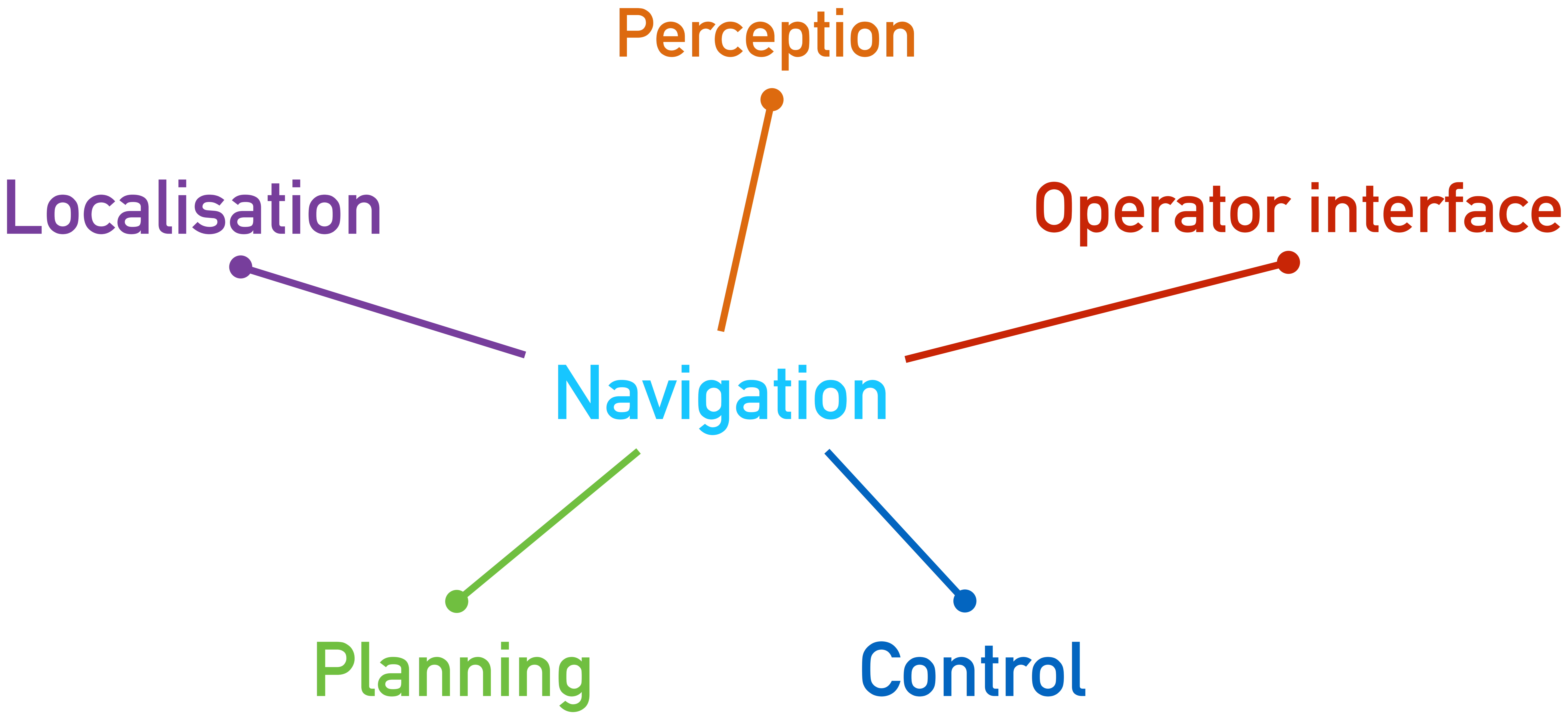
- Highly dependent on GPS in assisted modes.
- Requires sufficient piloting skills in non GPS-assisted modes.
- Chance of ‘flyaways’ due to bad GPS reception.
- Immediate need for robust GPS-agnostic navigation methods.
- No environmental awareness.
- Not truly autonomous.

CHALLENGES

- Multicopters are highly dynamic systems.
- They are inherently unstable and require active control strategies for stable flight.
- System dynamics are coupled and fast.
- Limited in terms of onboard computing and sensing hardware that can be carried.
- QoS for wireless datalinks to the MAV cannot be relied on in all environments.

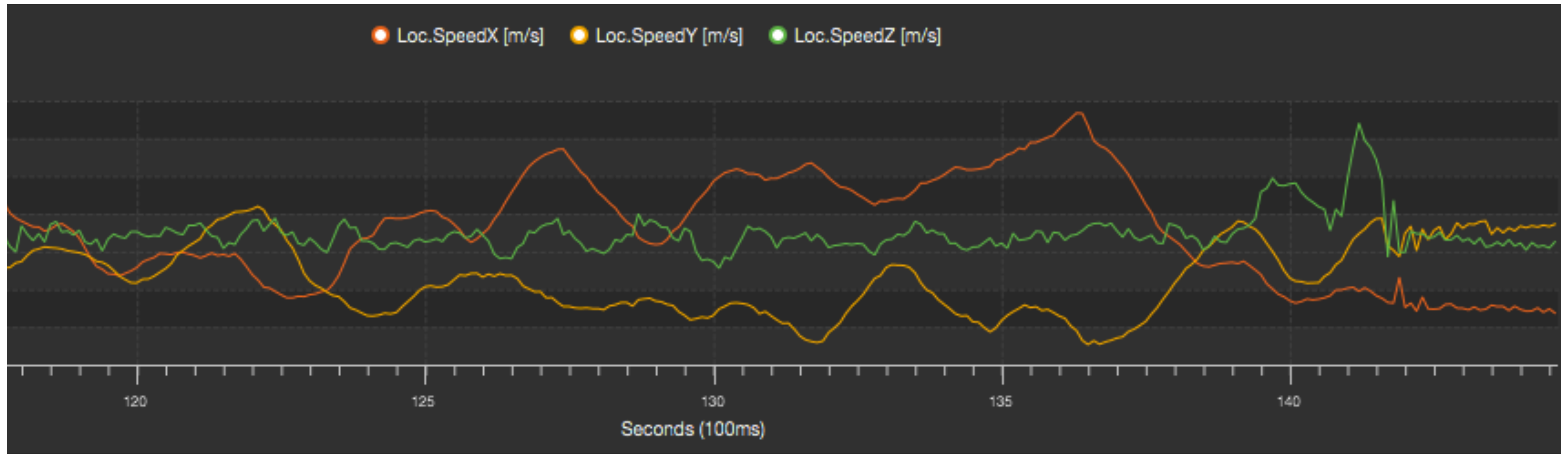


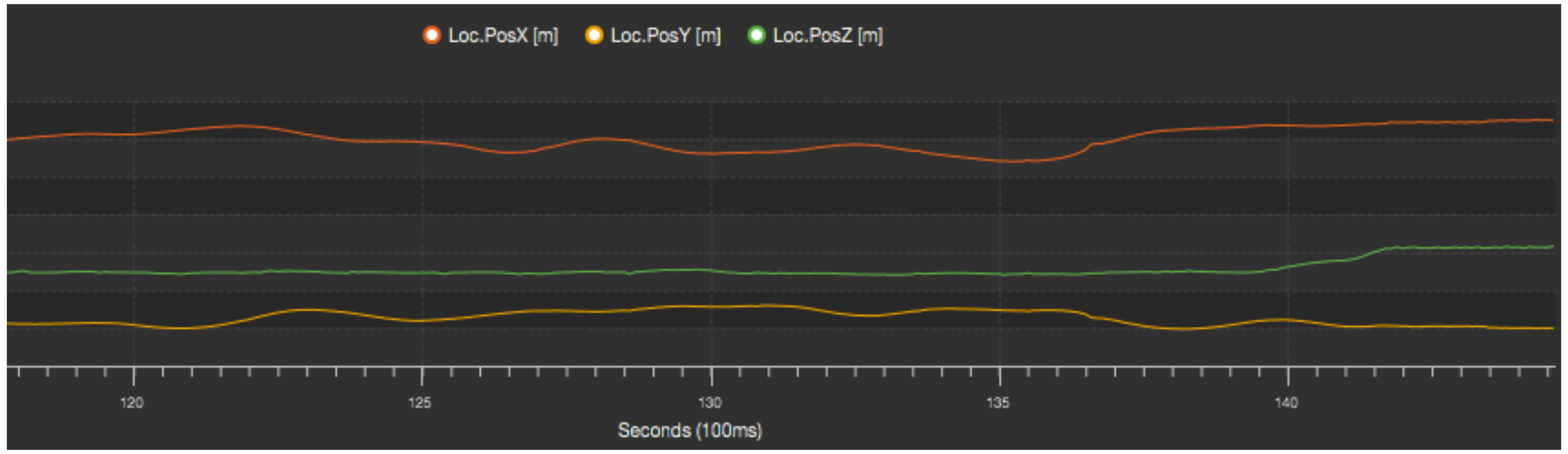
THE NAVIGATION PROBLEM

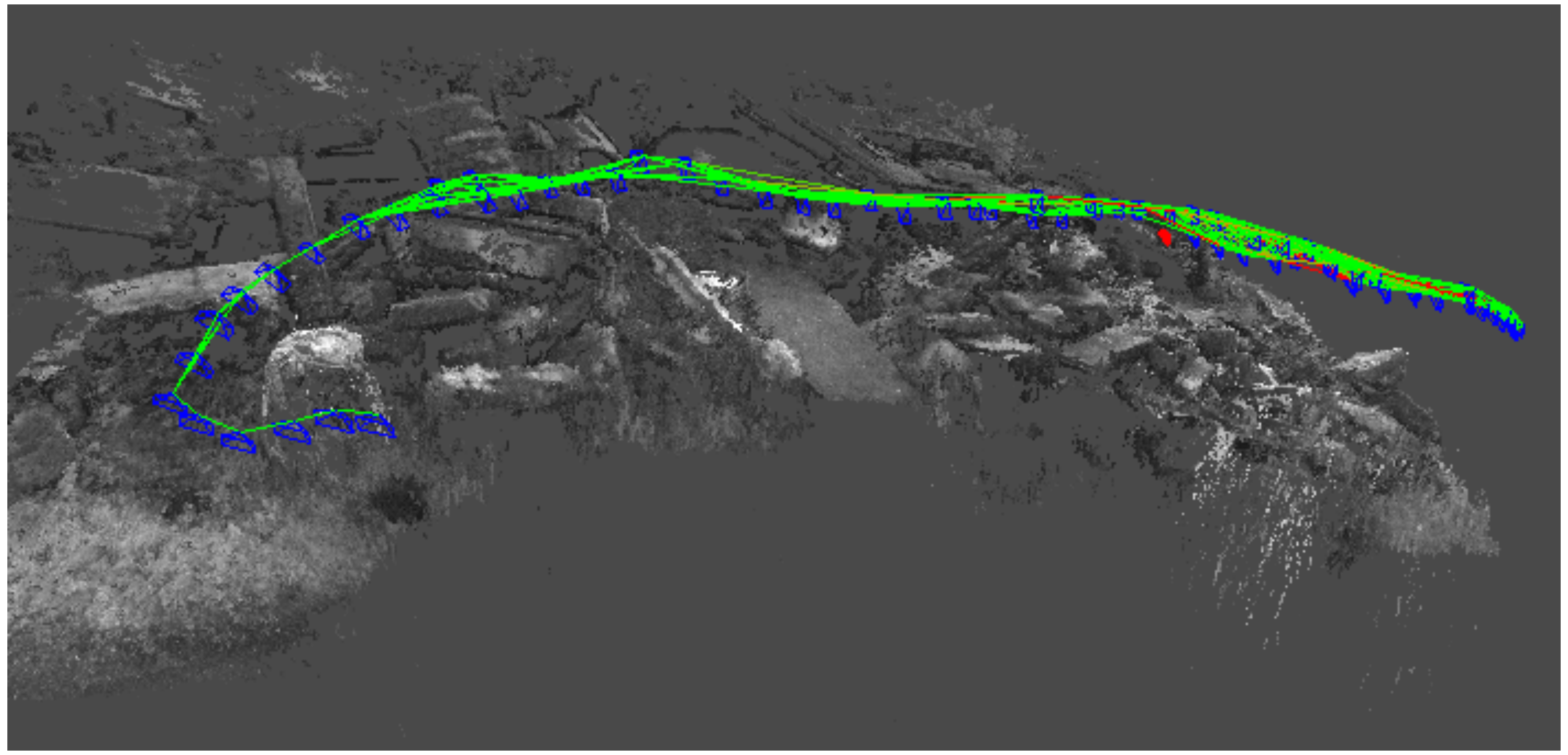


LOCALISATION

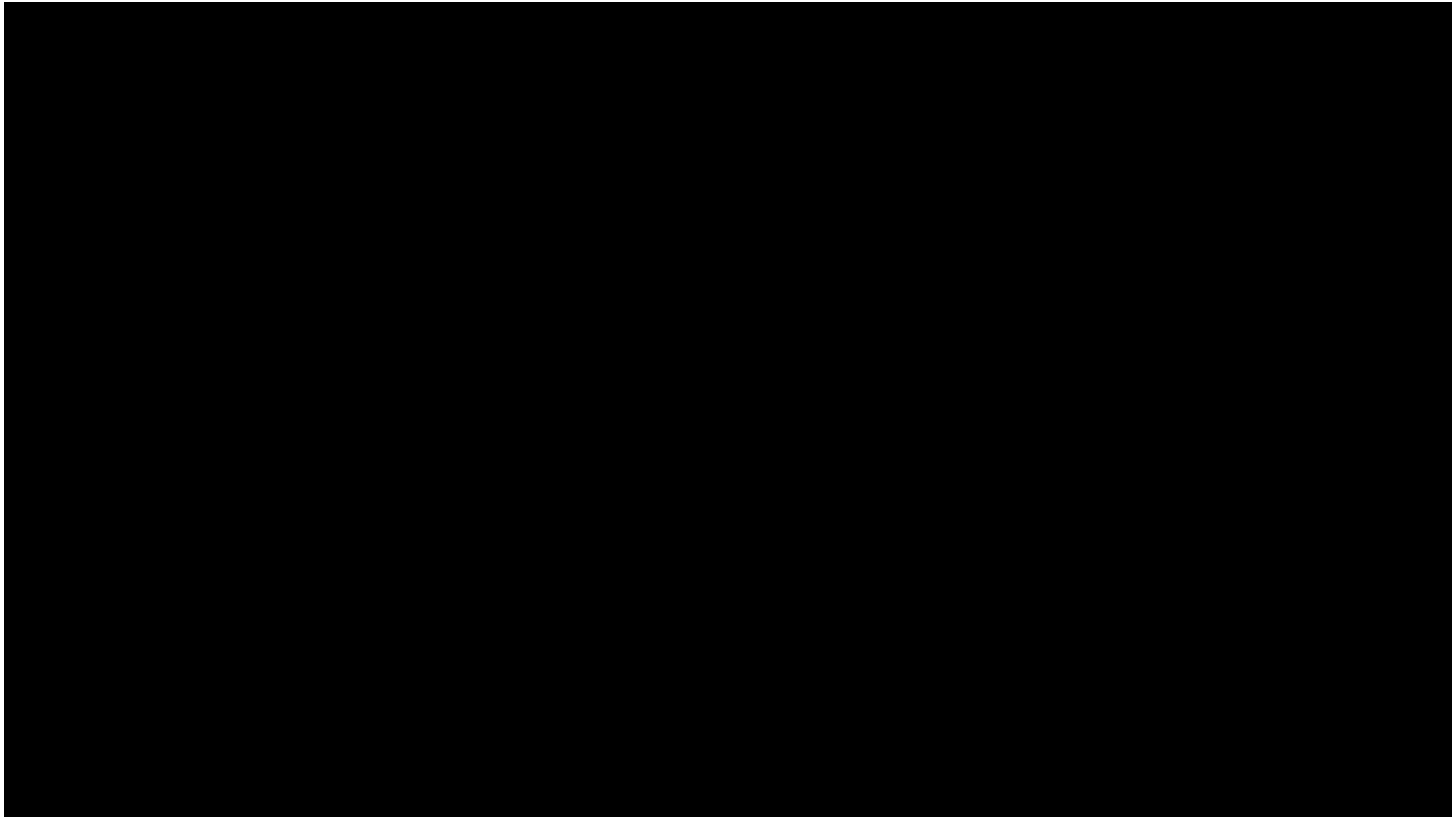
- We use a SLAM (Simultaneous Localisation and Mapping) technique on our robot.
- Visual SLAM is globally consistent, and centimetre-level accurate unlike GPS, and works indoors and outdoors.
- Tight fusion with time-synchronised inertial measurements greatly increases robustness and accuracy.





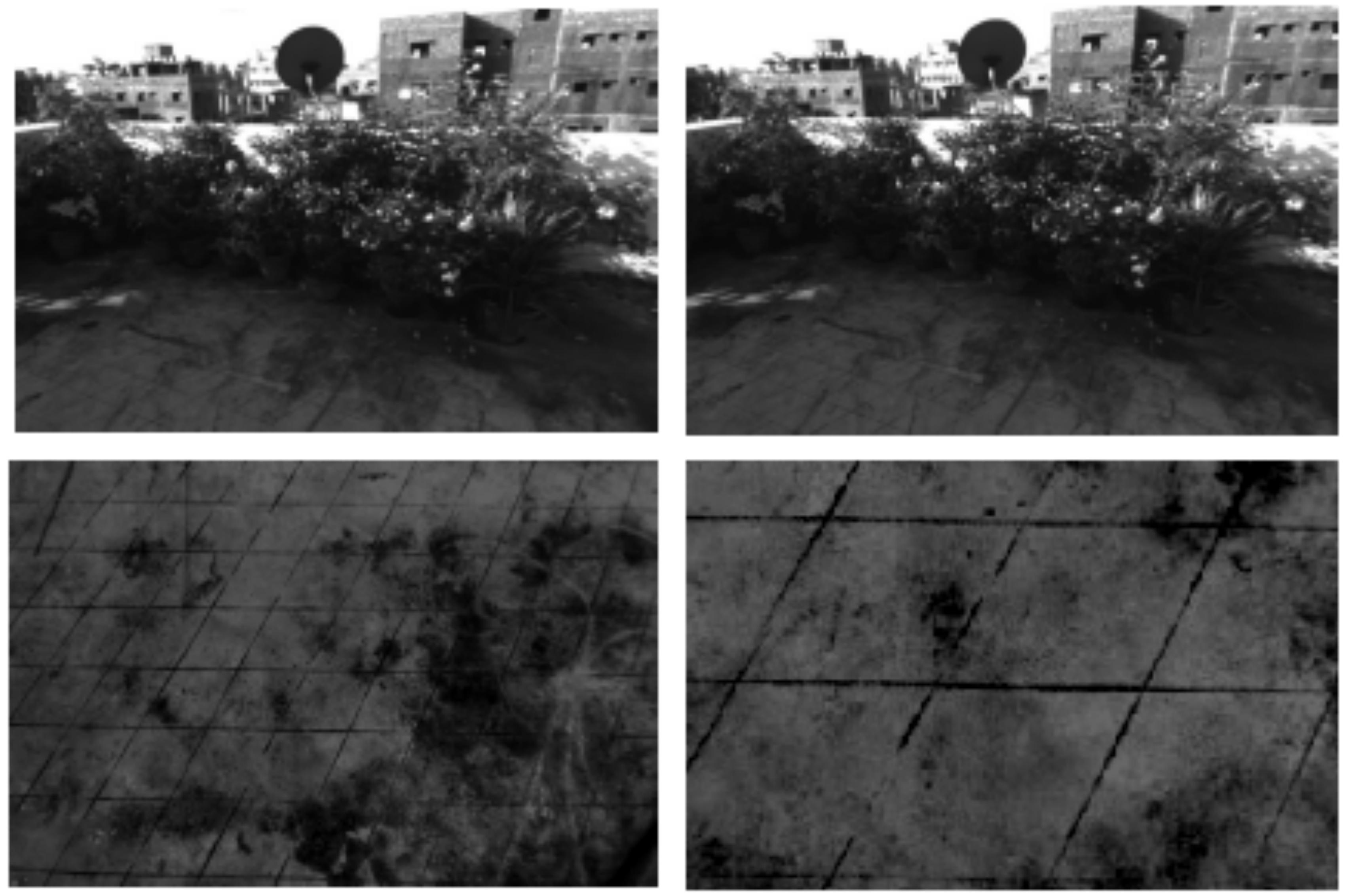


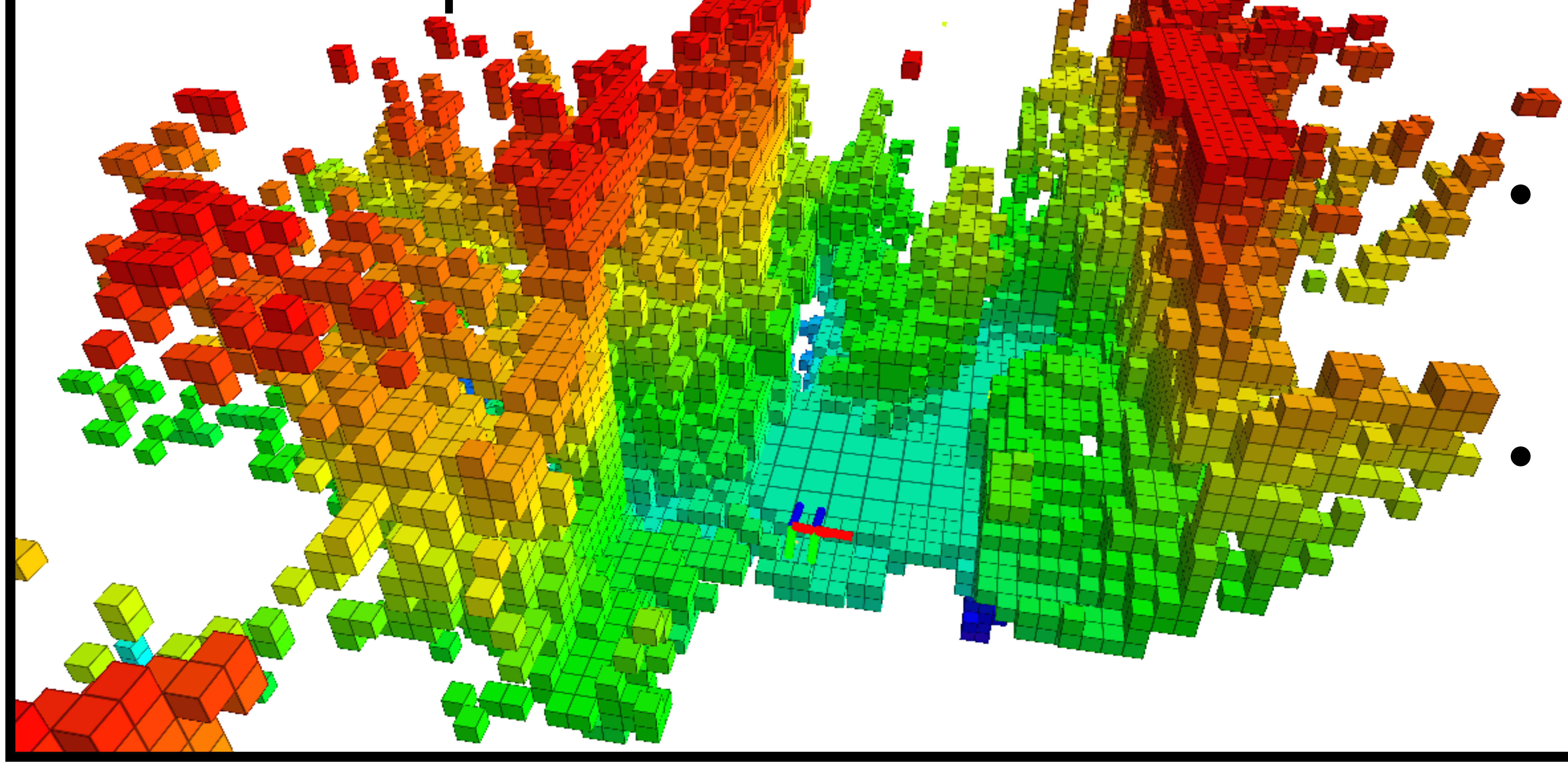
VISUAL-INERTIAL LOCALISATION



PERCEPTION

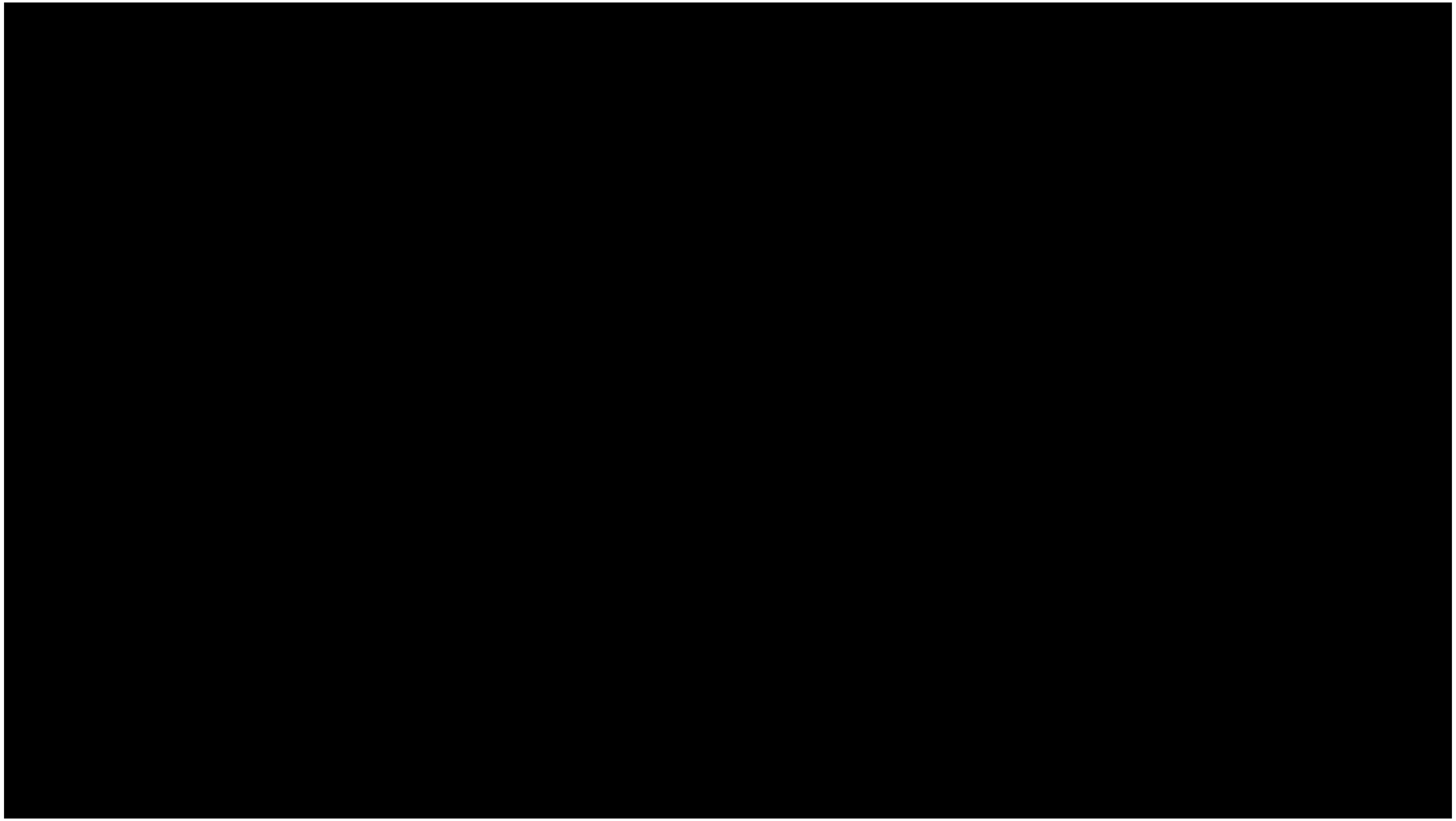
- Multiple cameras provide proprioceptive information about the environment.
- All the cameras and the IMU (Inertial Measurement Unit) are synchronised in time with respect to each other.





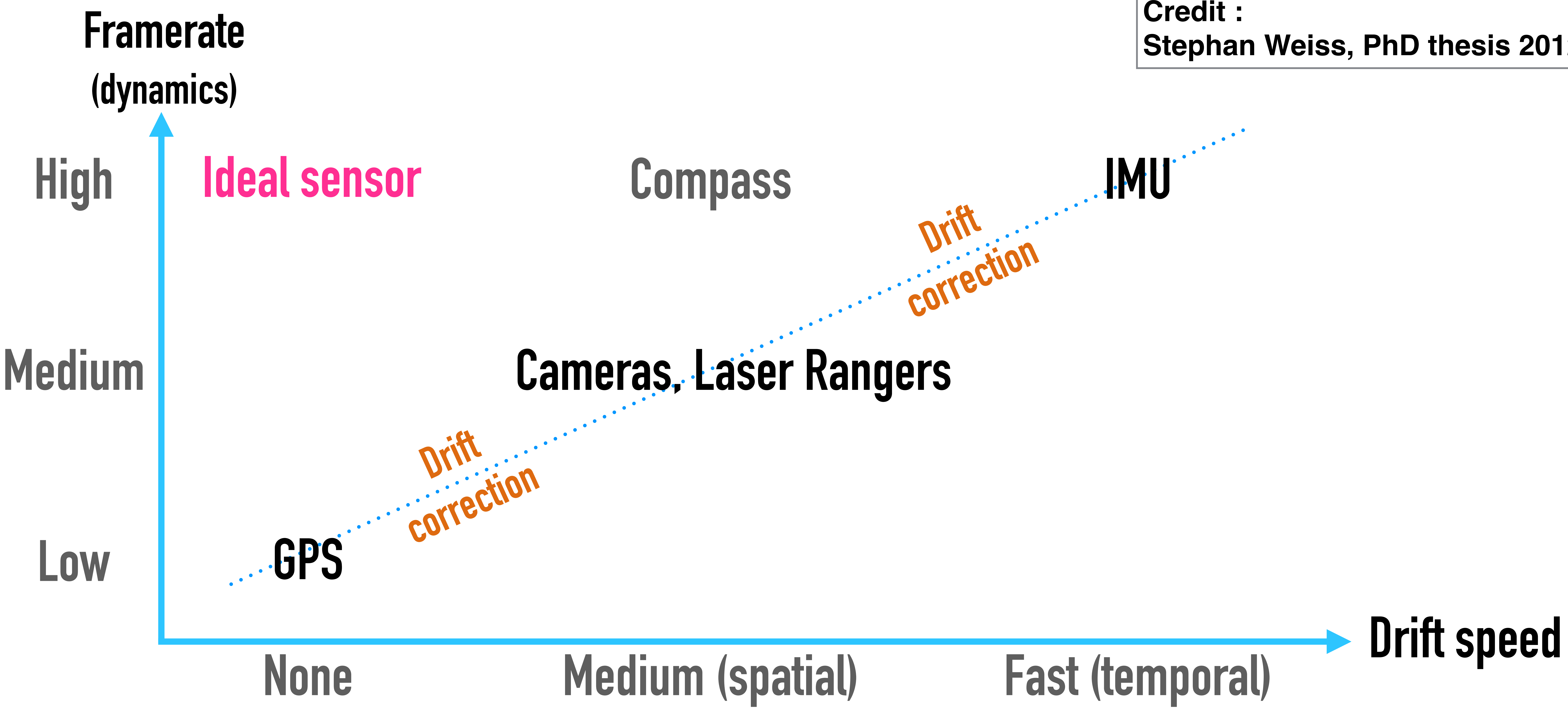
- Forward stereo cameras are used to compute depth images in realtime.
- Depth images are used to build a 3D map of the environment is built incrementally.

AUTONOMOUS EXPLORATION AND MAPPING



SENSING SUITE

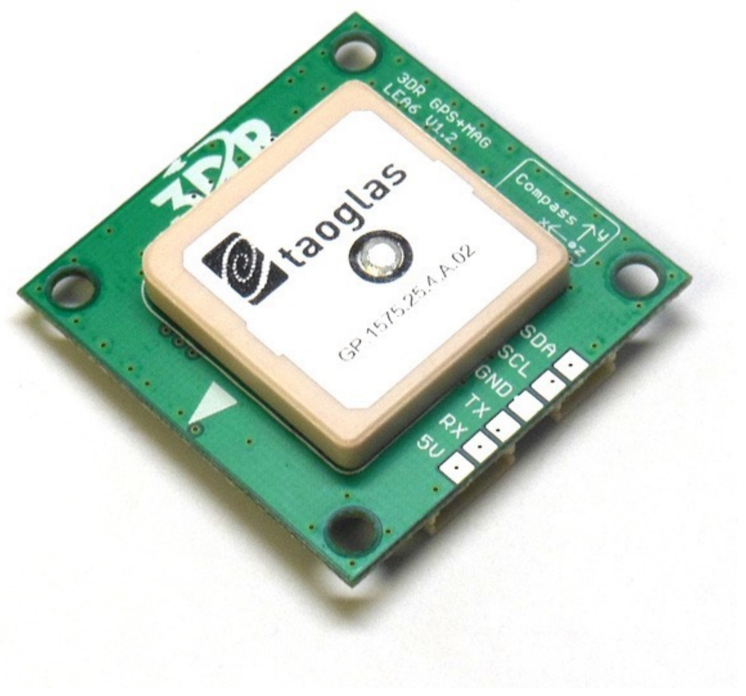
Credit :
Stephan Weiss, PhD thesis 2012

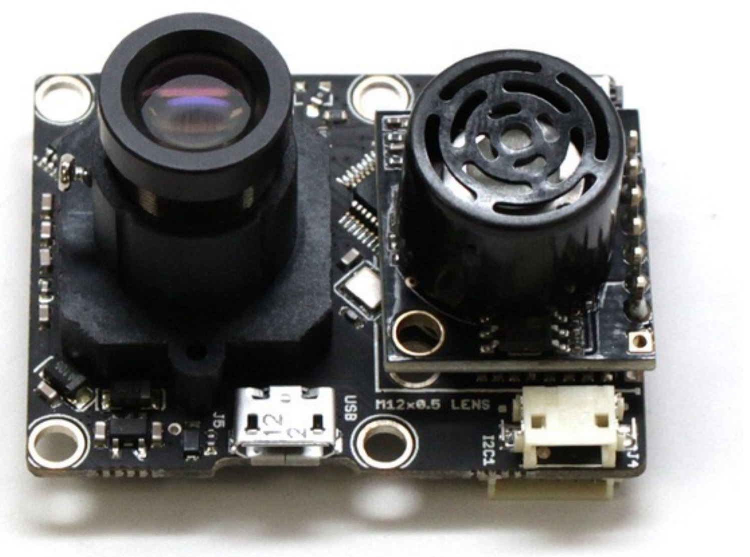


STATE ESTIMATION

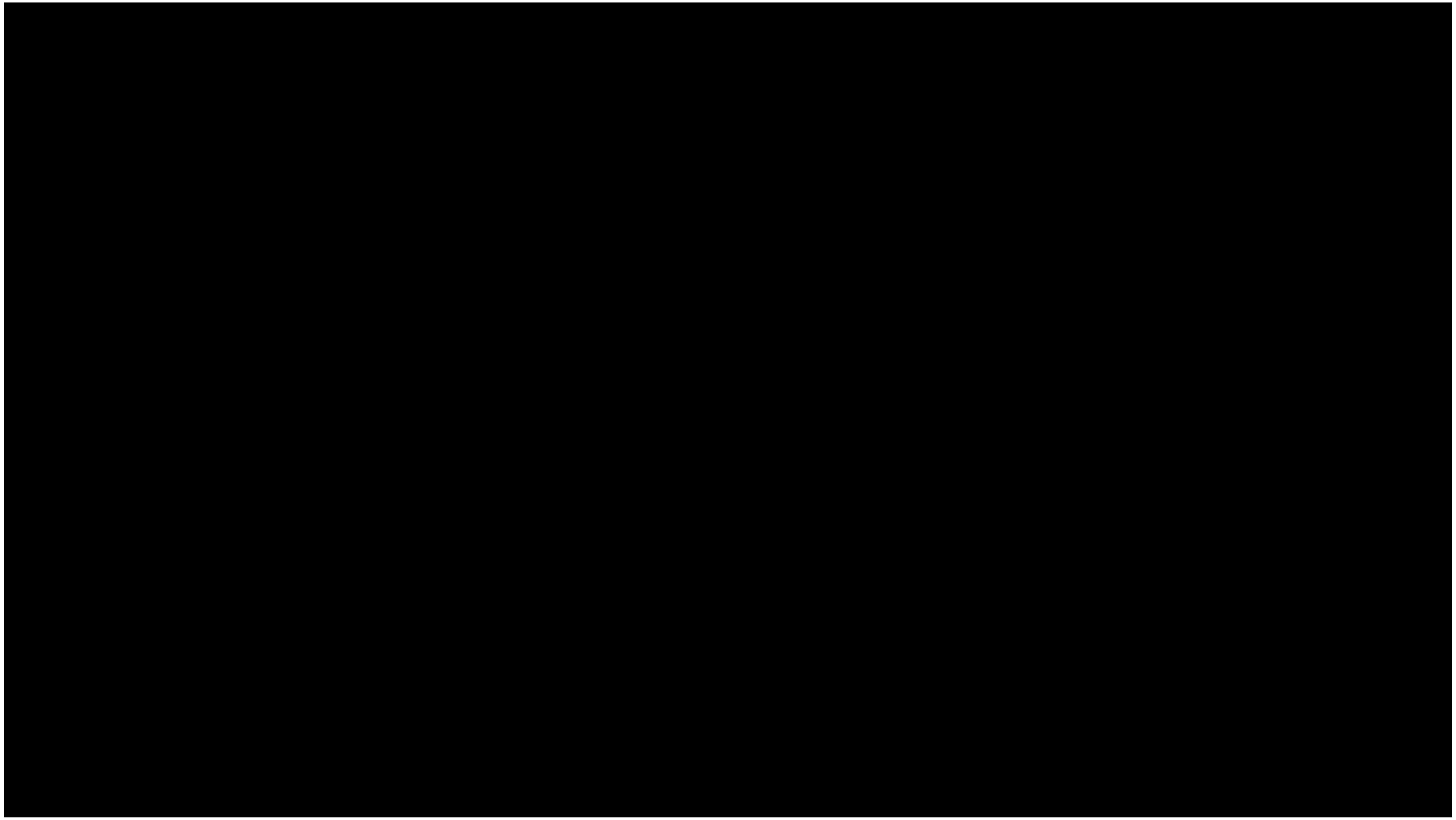
$$x_f = [\mathbf{p}_w^{i^T}, \mathbf{v}_w^{i^T}, q_w^{i^T}, \mathbf{b}_\omega^{i^T}, \mathbf{b}_a^{i^T}]$$

- The system is designed to navigate using all available sensors in the environment - GPS, Vision and Lidar.
- Sensor availability is not guaranteed - modular sensor fusion approach using a hybrid Kalman filter with fault detection is used.
- Even if a particular subset or module were to fail, the overall system performance would not be compromised.



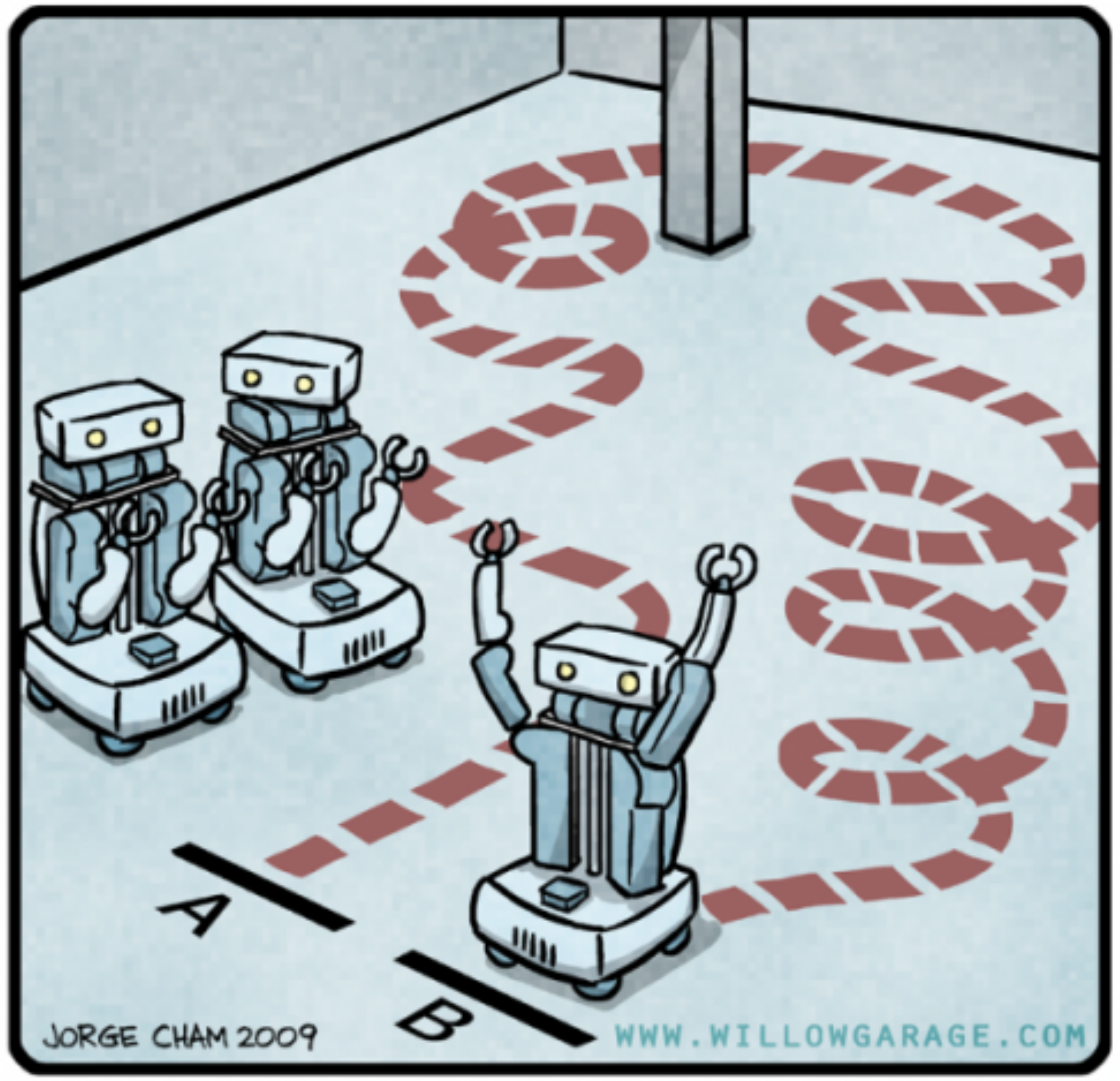


ROBUST MULTI-SENSOR FUSION



PLANNING AND CONTROL

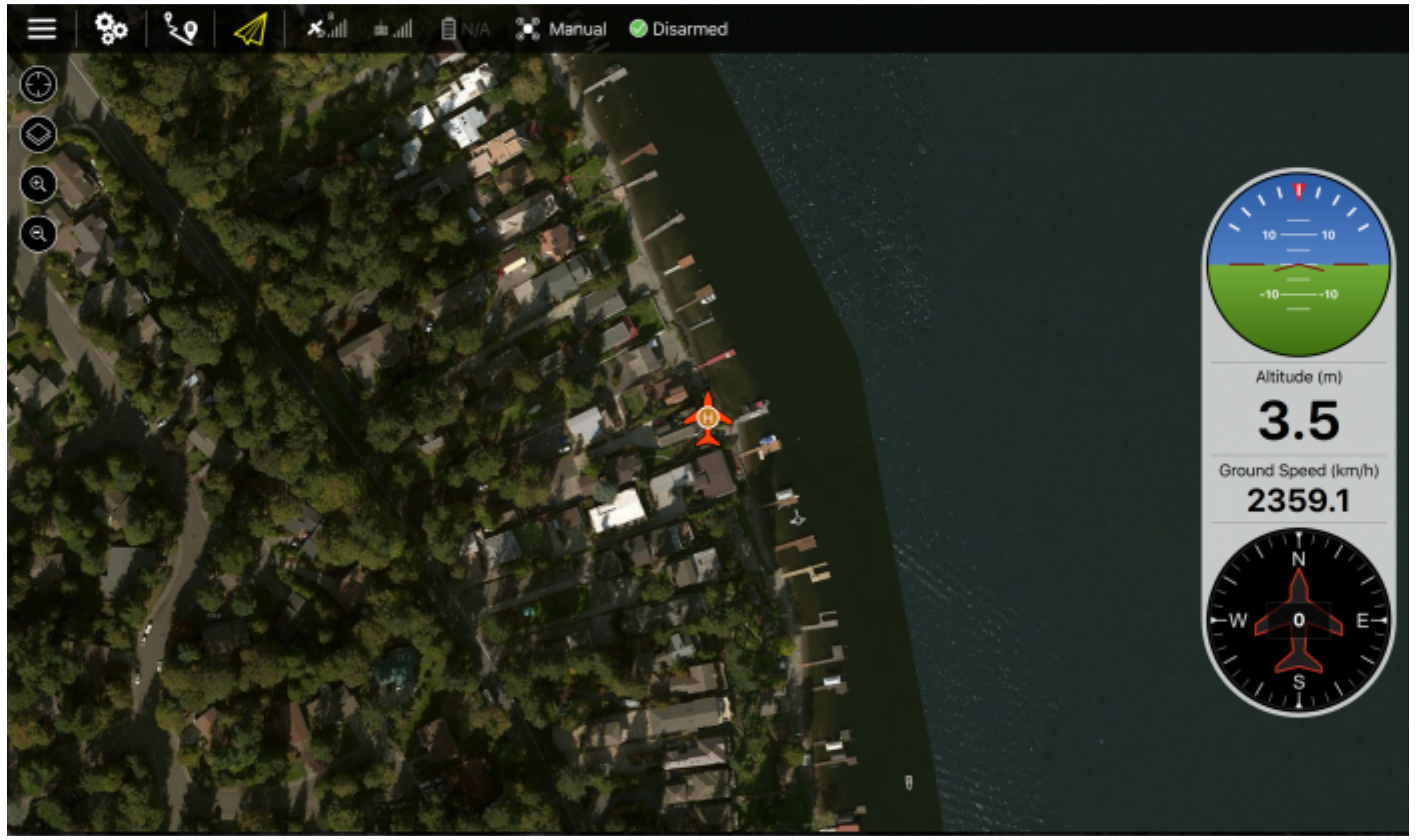
- The global volumetric map is used to continuously compute a collision-free trajectory for the vehicle.
- Assisted modes - planner only intervenes if the operator's high-level position commands could lead to a possible collision.
- Autonomous modes - planner computes optimal trajectories to completely explore the environment.



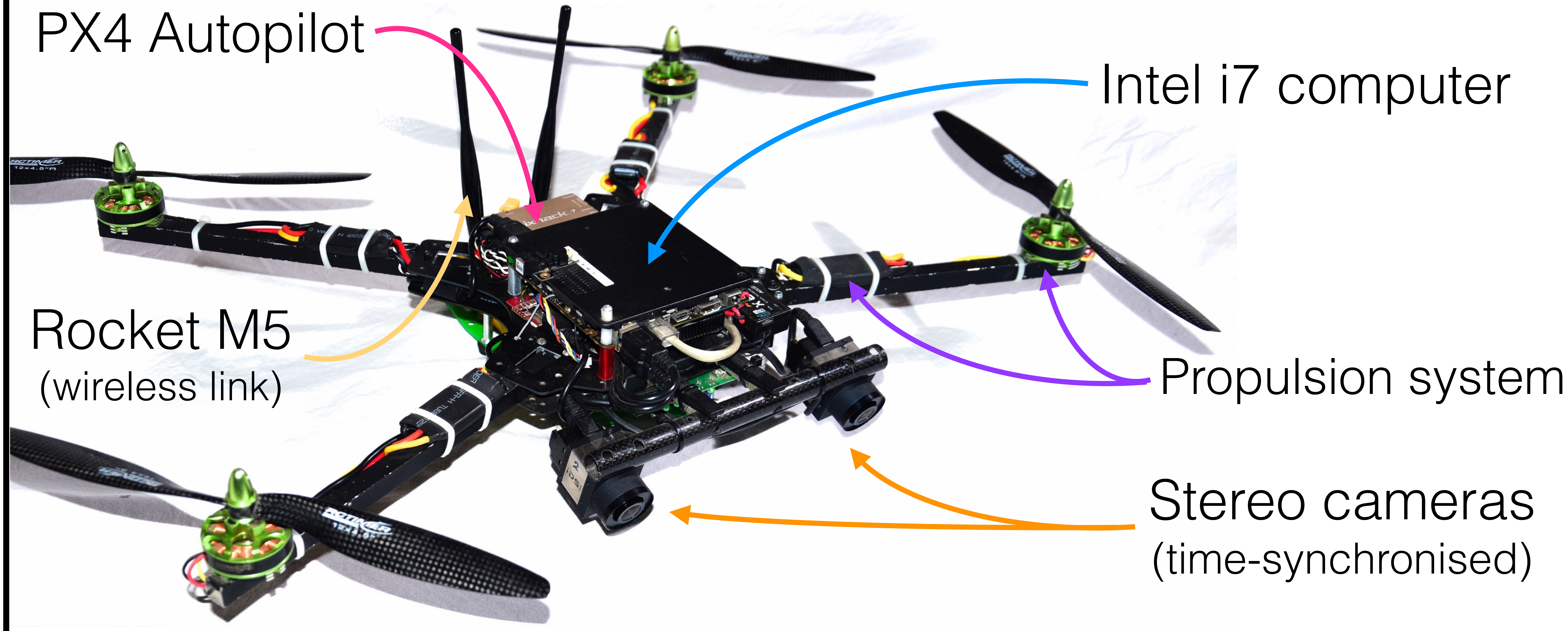
"HIS PATH-PLANNING MAY BE SUB-OPTIMAL, BUT IT'S GOT FLAIR."

OPERATOR INTERFACE

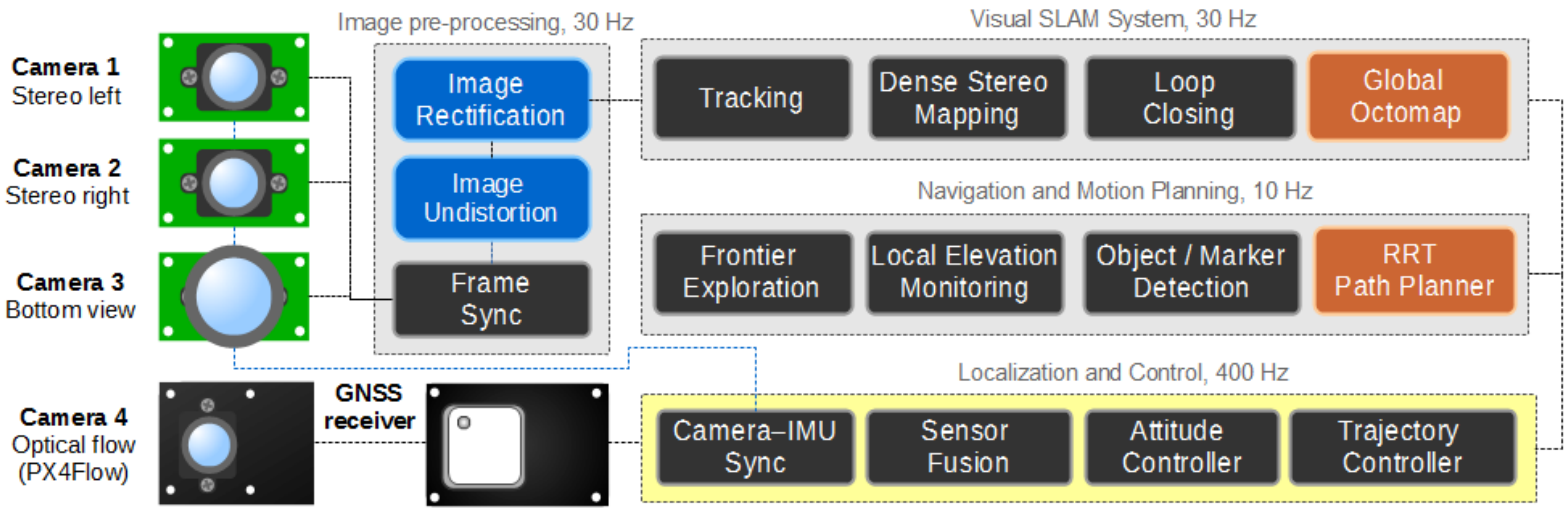
- We use a single laptop and a tablet for our ground control system.
- A long-range Ubiquiti modem is used as the primary air-to-ground datalink.
- The laptop runs SLAM visualisation and the tablet runs live FPV (first-person-view). The operator can use this high-definition feed to fly.



VEHICLE PLATFORM



NAVIGATION PIPELINE



VEHICLE PLATFORM

- The current-generation developmental prototype was designed after multiple iterations, building on top of our previous visual MAVs.
- Intel Core i7 onboard computer running Ubuntu 14.04 Server.
- Pixhawk autopilot running the PX4 Flight-stack.
- Ubiquiti Rocket M5 long-range wireless datalink.
- Forward facing stereo cameras, bottom facing optical flow camera and separate monocular camera.
- All low-level sensors like GPS, compass and actuator controllers (ESCs) are interfaced via the CAN bus.

SOFTWARE FRAMEWORK

- Software architecture follows a high-level / low-level separation model for maximal reliability. The flight core is isolated from the application-level processing to ensure stability of the core vehicle operation, independent of the high-level system state.
- Low-level tasks critical to flight control, like motor actuation and attitude estimation run on the PX4 Middleware on the NuttX RTOS.
- High-level tasks like computer vision run on the onboard Linux computer, on top of the ROS (Robot Operating System) Middleware.

THANK YOU!

Visit www.uasys.io/research for more!

Our open-source software stack is available at www.github.com/ProjectArtemis